

Claims

1. A method for determination of soil stiffness levels of a soil area, in which case one and the same self-propelled apparatus (1) is used not only to determine the absolute soil stiffness level (k_B) when located on at least one predetermined soil subarea (3) of the soil area but also to determine a plurality of relative soil stiffness levels (s) while crossing over a plurality of soil subareas of the soil area, in which case a vibration unit (5) of the apparatus (1) is moved to a predetermined soil subarea (3) in order to determine an absolute soil stiffness level (k_B), is left there and a first time-variable excitation force is applied by means of the vibration unit (5) in permanent contact with the soil surface, in which case the vibration unit (5) and the predetermined soil subarea (3) represent a single oscillating system and first data items of a first oscillation response of the oscillating system and second data items of the first time-variable excitation force are determined, and an absolute soil stiffness level k_B of the predetermined soil subarea (3) is determined from the first and second data items, the vibration unit (5) is moved to the soil surface of one of the soil subareas of the soil area in order to determine a plurality of relative soil stiffness levels (s) of a plurality of soil subareas, a second time-variable excitation force acts on the vibration unit (5) in such a way that the vibration unit (5) is lifted off the soil surface (2) and can thus be moved in a jumping manner to a plurality of the soil subareas, third data items of a second oscillation response of the oscillation of the vibration unit (5), caused by the second excitation force, and fourth data items of the oscillation of the second

excitation force are determined, and relative soil stiffness levels (k_B) of the soil subareas are determined successively and continuously over the soil area from the third and fourth data items.

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2. The method as claimed in claim 1, **characterized in that** the first time-variable excitation force is produced as a periodic first force with a maximum first oscillation level, which is directed at right angles (with the exception of an adjustment tolerance) against the soil surface **(2)**, and the periodicity is adjusted in such a manner that the oscillating system is at resonance, and the first and the second data items include the resonant frequency and a phase angle between a time sequence of maximum oscillation values of the first excitation force and of the first oscillation response.

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3. The method as claimed in claim 1 or 2, **characterized in that** the second time-variable excitation force is produced with a second periodic force, the second force has a maximum oscillation level which is greater than a first maximum oscillation level of a first periodic force of the first excitation force in such a way that the vibration unit **(5)** is lifted off the soil surface **(2)**, in which case the second maximum oscillation level of the second periodic force is directed obliquely to the rear with respect to the vibration unit towards the soil surface **(2)**, in order that the vibration unit **(5)** can be moved in the forward direction, and a lowest determined subharmonic frequency is determined, as the third data items of the second oscillation response, as a measure for a relative soil stiffness (s) with a relative soil stiffness (s) becoming greater, the lower the lowest determined subharmonic

oscillation is.

4. The method as claimed in one of claims 1 to 3,
5 **characterized in that** the amplitudes of a first
harmonic and of subharmonics during periodic
excitation of the vibration unit (5) by the second
excitation force are determined as third data
items of the second oscillation response,
preferably third data items are determined in soil
10 subareas, which are located at different points,
in a soil area together with the relevant absolute
values, and are stored in order to carry out a
calibration process which allows measured relative
values to be represented as absolute values, in
15 which case the soil area has the same soil
composition, except for a tolerance, the amplitude
values of the third data items with respect to the
maximum oscillation level of the excitation
oscillation with individual weighting factors to
20 be determined forming a sum, in which case the sum
value is the respective location-specific absolute
value, and the individual weighting factors are
determined from a plurality of measurements, in
which case the number of measurements corresponds
25 to the number of weighting factors, and in which
case the magnitude of the sum after a calibration
process is a measure of an absolute soil
compaction level or of an absolute soil stiffness
of a soil subarea which is just been moved over.
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5. The method as claimed in one of claims 1 to 4,
characterized in that the second force, which is
greater than a first maximum oscillation level of
a periodic force of the first excitation force, is
35 set in that at least one unbalance revolves, and
preferably at least two unbalances revolve in
opposite directions, and in particular two
unbalances revolve in opposite directions with a

mutual position offset, and their speed of revolution is correspondingly increased.

- 5 6. The method as claimed in one of claims 1 to 5,
characterized in that the second force, which is
greater than a first maximum oscillation level of
a periodic force of the first excitation force, is
set in that at least one unbalance revolves, and
the mass distribution of at least one unbalance is
10 varied radially and, except for soil tolerances, a
periodicity of the second excitation force
preferably corresponds to a resonant frequency of
the oscillating system.
- 15 7. The method as claimed in one of claims 1 to 6,
characterized in that respective position
coordinates of a soil subarea are determined for
relative or absolute soil stiffness levels, the
values of the soil stiffness are stored, in
20 particular together with the position coordinates,
and are transmitted, preferably to a control
center, in which case, in particular, the relative
values of the soil stiffness are stored together
with a predetermined positional coordinate grid.
- 25 8. An apparatus which propels itself on a soil
surface in order to carry out a method as claimed
in one of claims 1 to 7 for determination of soil
stiffness levels of a soil area with a vibration
30 unit, which can be moved into contact with the
soil surface, in which case the vibration unit **(5)**
can preferably also be used for soil compaction,
the apparatus **(1)** has a force production unit by
means of which a periodic first excitation force
35 and a second excitation force, which is not the
same as the first, and which act on the vibration
unit **(5)** can be produced, in which case the first
excitation force can be adjusted by means of the

force production unit in such a way that the maximum oscillation amplitude of the first excitation force can be directed at right angles against the soil surface, the period of the first excitation force can be adjusted in such a way that resonance of an oscillating system formed from the vibration unit and a predetermined soil subarea of the soil area can be achieved, and the vibration unit **(5)** never loses contact with the soil subareas of the soil area under the influence of the first excitation force, the second excitation frequency can be adjusted by means of the force production unit in such a way that the maximum oscillation amplitude of the second excitation force can be directed obliquely with respect to the soil surface and the excitation force is sufficiently large that the vibration unit loses soil contact in a jumping manner, as a measurement means with which oscillation data of the excitation force as well as oscillation data of the vibration unit can be determined as an oscillation response, and has an evaluation unit by means of which at least one absolute value of a soil stiffness of a predetermined soil subarea of a soil area can be determined by means of the first excitation force from the oscillation data of the excitation force and the data of an oscillation response of the vibration unit **(5)**, and a plurality of relative values of soil stiffnesses of predetermined soil subareas of the soil area can be determined by means of the second excitation force.

9. The apparatus as claimed in claim 8, **characterized in that** the vibration unit **(1)** is part of a so-called vibration plate.

10. The apparatus as claimed in claim 8 or 9,

5 **characterized in that** the vibration unit (5) has
an adjustable steady-state unbalance moment and/or
an adjustable excitation frequency for at least
one rotating unbalance, in order that relative
10 soil stiffness levels can be determined with a
first unbalance moment and/or at a first
excitation frequency, preferably together with
soil compaction, and absolute soil stiffness
levels can be determined with a second unbalance
15 moment, which is not same as the first unbalance
moment and/or at a second excitation frequency,
which is not the same as the first excitation
frequency, and soil compaction can be carried out
with a third unbalance moment, which is not the
20 same as the first or second unbalance moment,
and/or at a third excitation frequency, which is
not the same as the first or second excitation
frequency.

20 11. The apparatus as claimed in one of claims 8 to 10,
characterized in that the first or second
unbalance moment can be produced by two unbalances
which revolve in opposite directions but at the
same rotation speed, in which case the rotation
25 speed can be adjusted in order to produce
different excitation frequencies.

30 12. The apparatus as claimed in one of claims 8 to 11,
characterized by indication means, by means of
which compaction levels can be indicated, in order
to find out whether a compaction increase which
exceeds a predetermined tolerance can still be
achieved by further passes.

35 13. The apparatus as claimed in one of claims 8 to 12,
characterized in that the measurement means has a
data memory, an evaluation unit and a position
detection unit for determination of position

coordinates of a soil area on which the apparatus is currently located, in which case the determined relative and absolute soil stiffness levels can be stored in the data memory, preferably together with the associated position coordinates, and soil-specific weighting values, which can be stored in the data memory, can be determined from stored soil stiffness levels by the evaluation unit, in which case the relative values of the soil stiffness can be converted to absolute values by means of the weighting values, and a transmission unit is preferably provided, by means of which these stored data items can be transmitted to a control center and, in particular, the apparatus has an indicator for the absolute values and preferably for the relative values.